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A request for examination has been made in accordance with § 44 of the Patent Act.

Device and method to encourage the surface uptake and/or surface release of a substance by a fluid

In order to create a device to encourage the surface uptake and/or surface release of a substance by a fluid, comprising a flow channel in which a laminar flow of the fluid can be formed, it is suggested that at least one flow guide device be provided, which is positioned in the flow channel in such a way, and formed in such a way, that it brings about a spatial rearrangement of fluid layers in the laminar flow.

Description

[0001] The invention relates to a device to encourage the surface uptake and/or surface release of a substance by a fluid, comprising a flow channel in which a laminar flow of the fluid can be formed.

[0002] The invention also relates to a method of encouraging the surface uptake and/or surface release of a substance by a fluid which is moving in laminar flow.

[0003] When a fluid is in laminar flow, internal friction is present essentially without turbulence. The Reynolds number of a flow of this type is very low. In channel flow, the change from laminar flow to turbulent flow takes place at a Reynolds number of 2300, when friction is observed only inside the flowing fluid between adjacent fluid layers, the separate fluid layers in laminar flows moving at different velocities.

[0004] For example, laminar flows occur when atmospheric oxygen is added to electrochemical cells as an oxidising agent. In fuel cells, for example, atmospheric oxygen is supplied to catalytically active, flat extended electrodes in order to act as an oxidising agent in the electrochemical reaction. The air itself is distributed over the surface of the electrodes by means of one or more flow channels. In particular, a gas diffusion electrode is positioned at one side of the flow channels, so that the oxygen from the air is able to diffuse over a wide area to the gas diffusion electrode. Commercial fuel cells have a high power density and integral density, so that the flow channels have small structures (smaller than 1×1 mm^2, for example). In practice, the flow velocities are relatively low (a few metres per second at most). These give correspondingly low Reynolds numbers, resulting in the formation of very stable laminar fluid flows in flow channels of this type.

[0005] The purpose of the invention is to create a device and method by which the uptake and/or release of a substance by the fluid in laminar flow, over the surface of this substance, is optimised.

[0006] This purpose is fulfilled by the device mentioned earlier, in that there is at least one flow guide device which is positioned in the flow channel in such a way, and formed in such a way, that it brings about a spatial rearrangement of fluid layers in the laminar flow.

[0007] As a result of the laminar flow of the fluid there is no turbulent intermingling of the fluid within the flow channel. This can result in the formation of a concentration gradient of the substance in the fluid which is to be taken up or released, starting from the uptake surface or release surface. For example, where air is the fluid and oxygen is the substance to be released, the air in the areas near the surface is depleted in atmospheric oxygen. Because, within the flow channel, the substance can essentially only be transported across the separate fluid layers by diffusion at right angles to the direction of the laminar flow, the uptake or release of the substance is impeded by the laminar flow of the fluid.

[0008] It is known that turbulence-generating structures – such a turbulators or turbulence promoters – can be used to encourage the intermingling of the fluid; this in

turn encourages the surface uptake and/or surface release of a substance because it acts against the formation of a concentration gradient of the substance in the fluid. Turbulence-generating structures of this type operate on the principle of bringing about a change from laminar to turbulent flow, i.e. by producing high Reynolds numbers. To do this, however, the speed of flow has to be increased; moreover, the dimensions of the flow channel have to be sufficiently large. In addition, turbulence-generating structures of this type cause severe pressure losses.

[0009] Under the invention, the laminarity of the flow is retained even though the fluid layers are rearranged within the laminar flow; as a result, the formation of a concentration gradient of the substance in the fluid is counteracted.

[0010] The surface uptake or surface release of the substance by the fluid is improved. This counteracts the impeded movement of the substance within the laminar flow of the fluid. Because there is no turbulent intermingling, only very small losses of pressure occur.

[0011] The device of the invention can thus be used to advantage in fuel cells, because the surface release of oxygen in a laminar air flow is encouraged, while, at the same time, the cross-section of a flow channel is reduced only minimally, retaining the low-loss laminar nature of the flow. Particularly in the case of fuel cells for mobile use (such as fuel cells for a motor vehicle), small losses of pressure can lead to a serious drop in the efficiency level of the system. The device of the invention, which ensures the retention of the laminar nature of the flow, means that detrimental pressure losses of this type can be largely avoided.

[0012] It is beneficial for the at least one flow guide device to be positioned and formed in such a way that, by means of it, a transverse speed component is imparted to the layer flows of the laminar flow. As a result of this, layer flows particularly from areas that are lower in relation to the surface of the laminar flow can be deflected towards the surface, and layer flows from areas close to the surface can be deflected to lower areas, in order in this way to counteract the formation of a concentration gradient of the substance in the fluid, and thus to reduce the restriction on the movement of the substance in relation to the surface uptake or surface release.

[0013] It is beneficial if, in the process, the at least one flow guide device is positioned and formed in such a way that there is a rearrangement of the fluid layers of the laminar flow, so that fluid layer flows from areas closer to the uptake surface or release surface of the fluid are deflected to areas further away. In this way, fluid layers that have a low level of the substance are deflected during surface release, and fluid layers with a high level of the substance are deflected during surface uptake, towards substance-rich or substance-poor areas respectively, on the basis of their distance from the surface.

[0014] It is beneficial if the at least one flow guide device is likewise positioned and formed in such a way that fluid layer flows that are further away from the uptake surface or release surface of the fluid are deflected to areas closer to this surface. During the surface uptake of a substance, fluid layer flows from substance-poor areas are thus deflected towards the surface, so that they can take up the substance there;

during release, fluid layers with a higher substance content are deflected towards the surface in order to provide improved substance release.

[0015] It is most particularly beneficial if the at least one flow guide device is positioned and formed in such a way that the flow within the flow channel is essentially free of turbulence. In this way there will be no, or only very small, losses in pressure, and, in particular, there will also be no pressure oscillations which could reduce the efficiency of (for example) a fuel cell to which atmospheric oxygen is being supplied.

[0016] It is beneficial if the at least one flow guide device is positioned and formed in such a way that fluid flows of different fluid layers intersect each other. This causes an effective spatial rearrangement of fluid layers, in this way counteracting the formation of a concentration gradient of the substance in the laminar flow, and thus improving the surface uptake or surface release of the substance.

[0017] It is beneficial if the at least one flow guide device includes a structure, the dimensions of which vary at right angles to the direction of the laminar flow. In this way, the fluid layer flows of individual fluid layers are given a transverse speed component in order thus to bring about a spatial rearrangement of the layers.

[0018] It is beneficial if the at least one flow guide device is positioned and formed in such a way that an essentially regular rearrangement of fluid layers takes place along the flow channel. The lengthwise direction of the flow channel is defined as being parallel to the main flow direction of the laminar flow. Positioning and form of this type ensure that conditions at the uptake surface or release surface of the fluid in the flow channel are essentially similar, and that highly localised increases or reductions in the concentration of the substance in the layers close to the surface are avoided.

[0019] It is beneficial if the at least one flow guide device includes a number of flow-guiding structures that are positioned at regular intervals in relation to the lengthwise direction of the flow direction[1]. In this way it is possible to achieve, in a simple manner, an oscillatory spatial rearrangement of the layers which has a low standard deviation with regard to an average concentration of the substance at the surface, thereby avoiding highly localised concentration gradients.

[0020] In a first embodiment, the at least one flow guide device has a flow deflector that imparts a swirl motion to the fluid in the laminar flow. In simulation calculations it has been shown that structures of this type can, while costing little to manufacture, bring about a significant improvement, for example in the surface release of a substance by the fluid in laminar flow. For example, a twelve per cent increase in output in current density at the flow deflector was achieved, using a flow deflector on electrodes of the fuel cell, in the efficiency of a fuel cell that uses air as the fluid in laminar flow and oxygen as the substance to be released.

[0021] In particular, it is beneficial if the flow deflector has a spiral construction in order to impart a swirl motion to the fluid in the laminar flow.

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[1] Translator's note: I think this should perhaps be "flow channel" rather than "flow direction".

[0022] It is beneficial if a lengthwise axis of the flow deflector lies parallel to the lengthwise direction of the flow channel. In this way, the main flow direction of the laminar flow is retained, at the same time providing for the spatial rearrangement of the fluid layer flows.

[0023] In a variant of one embodiment, the flow deflector is positioned in the flow channel. For this purpose it can be inserted, for example, into the flow channel.

[0024] In another variant of one embodiment, the flow deflector is formed by the channel walls themselves. To this end, the channel walls can have a concave structure, i.e. "positive" grooves can protrude from the channel walls. It is also possible for the channel walls to have a convex structure; this means that "negative" grooves are sunk into the channel walls.

[0025] In another embodiment, the flow-changing device includes one or more displacers, which form obstacles for the flow inside the flow channel. The laminar flow is able to "peel off" partially at these displacers, i.e. a deflection of fluid layer flows of the laminar layer flow is effected, which in turn leads to a spatial rearrangement of the layers. Displacers of this type can be made at particularly low cost, and can be inserted simply, for example into an existing flow channel.

[0026] In a variant of this embodiment, a displacer is made in a wedge shape. Simulation calculations have shown that wedges of this type can provide increases in output of about 10 % in fuel cells, with negligible pressure losses.

[0027] It is beneficial if a wedge-shaped displacer is positioned in such a way that its sloping face is turned towards the direction of the laminar flow. This causes an effective "peeling" action, in order in this way to bring about an effective spatial rearrangement of fluid layers.

[0028] It is most particularly beneficial if the flow guide device includes at least one pair of wedge-shaped displacers. It has been shown that – for example, where a pair of displacers like this is installed – the pressure loss is negligible over the whole length of a flow channel with an effective release surface, and there is an increase in output of about 10 %, for example in a fuel cell.

[0029] In order to bring about an effective rearrangement of the layers, it is particularly beneficial if the sloping faces of the wedges of a pair of displacers are positioned at right angles to each other.

[0030] It is also beneficial if the displacers of a pair of displacers are positioned offset to each other in a transverse direction of the flow channel in order to bring about an effective rearrangement of the layers.

[0031] It is also beneficial if the sloping faces of the wedges of a pair of displacers have component vectors acting in opposite directions relative to the lengthwise direction of the flow channel, in order to bring about an effective "peeling" of fluid layer flows, in order to effect, in turn, a spatial rearrangement of the layers.

[0032] In a variant of one embodiment, a displacer is positioned and formed in such a way that fluid layer flows from first walls of the flow channel can be deflected towards second walls of the flow channel. In another variant, a displacer is positioned and formed in such a way that fluid layer flows can be deflected from closed walls of the flow channel towards open channel walls. In particular, these two variants can also be combined in order to make possible an effective spatial exchange of fluid layers.

[0033] The invention also relates to use of the said device in an electrochemical cell. Because, under the invention, the need to change from laminar flow to turbulent flow is avoided, the pressure loss that occurs is, at most, very low. In addition there is no need to apply any non-standard operating conditions – high flow speeds, for example – to the electrochemical cell. By using the device of the invention, the electrochemical cells can be operated within their optimum parameter range, an optimum supply of oxygen being assured. The device can, for example, be used in an electrolytic cell.

[0034] It is most particularly beneficial to use the device of the invention in a fuel cell. Fuel cells, and especially fuel cells for mobile use – in a motor vehicle, for example – have high integral densities, and the demands placed on the efficiency of the system are great. The flow channels used in them have small dimensions, and the flow speed is relatively low. By using the device of the invention, a good supply of oxygen, for example, is assured from a laminar air flow to the electrode surfaces, pressure losses being largely avoided because no change is necessary from laminar to turbulent flow, i.e. the device can continue to be operated at low Reynolds numbers. In particular, the flow channel leads here to an electrode in order to supply it with oxygen. The oxygen comes, in particular, from a laminar flow of air.

[0035] The purpose mentioned is also fulfilled, under the invention, by a method as given earlier, in which fluid layers of the laminar flow are rearranged by means of a flow guide device.

[0036] This method possesses the benefits already described in connection with the device of the invention.

[0037] Other beneficial developments of the method and their benefits have already been described in connection with the device of the invention and its use.

[0038] The following description of preferred examples provides, in conjunction with the drawings, a more detailed explanation of the invention.

[0039] Figs. 1a and 1b show, in diagrammatic form, a laminar flow inside a closed channel of a rectangular shape, in a lengthwise view (Fig. 1a) and in cross-section (Fig. 1b);

[0040] Figs. 2a and 2b show the surface release of a substance from a fluid flowing in a laminar manner inside a flow channel, the flow channel being open facing the release surface of the fluid, in a lengthwise view (Fig. 2a) and in cross-section (Fig. 2b);

[0041] Fig. 2c shows the changes in the concentration of the release substance over the depth of the flow channel as in Figs. 2a and 2b;

[0042] Figs. 3a, 3b, 3c and 3d each show a variant of a flow deflector acting as the flow guide device, positioned inside a flow channel;

[0043] Fig. 4 shows the ratio of the local current density of an electrochemical cell to which air is being passed in a laminar flow in a flow channel, a flow deflector as in Fig. 3a being positioned in a part section of the flow channel;

[0044] Fig. 5 shows another variant of a flow deflector, which is positioned inside a flow channel that is semicircular in section, shown diagrammatically in lengthwise view parallel to the surface (right-hand part) and in cross-section (left-hand part);

[0045] Fig. 6a shows the flow deflector as in Fig. 5, in lengthwise view perpendicular to the surface of the fluid;

[0046] Fig. 6b shows a cross-section of the flow channel as in Fig. 6a, a concave structure being formed in the walls of the flow channel;

[0047] Fig. 6c shows a cross-section of the flow channel as in Fig. 6a, a convex structure being formed in the walls of the flow channel;

[0048] Fig. 7a shows another example of a flow guide device, which is positioned in a flow channel with a square cross-section, the flow guide device incorporating a wedge-shaped displacer; shown in lengthwise view parallel to the fluid surface (right-hand part) and in cross-section (left-hand part);

[0049] Fig. 7b shows the flow channel as in Fig. 7a, in a lengthwise view at right angles to that of Fig. 7a;

[0050] Fig. 7c shows another example of displacers positioned in a flow channel;

[0051] Fig. 8a shows another example of a flow guide device with displacers, one pair of wedge-shaped displacers being positioned in the flow channel; shown in lengthwise view (right-hand part) and in cross-section (left-hand part);

[0052] Fig. 8b shows a lengthwise view of the flow channel as in Fig. 8a, at right angles to the view in Fig. 8a;

[0053] Fig. 8c shows another example of displacers arranged in pairs;

[0054] Fig. 9 shows the current density I of a fuel cell, to which is supplied, via a flow channel as in Fig. 8a, oxygen as an oxidising agent by means of air in laminar flow, over the channel length P of the flow channel; a comparison is made between the current density when a flow guide device with wedge-shaped displacers arranged in pairs is in position, and the same without any such displacers. The graph is the result of a simulation;

[0055] Fig. 10a shows another example of a flow guide device in lengthwise view (right-hand part) and in cross-section (left-hand part);

[0056] Fig. 10b shows the flow channel as in Fig. 10a in a lengthwise view at right angles to that shown in Fig. 10a;

[0057] Fig. 10c shows another example of a flow guide device which includes displacers positioned in the flow channel;

[0058] Figs. 11a and 11b show another example, in lengthwise view (Fig. 11a, right-hand part; Fig. 11b) and in cross-section (Fig. 11a, left-hand part), of a displacer positioned in a flow channel with a square cross-section, the displacer in the variants shown being formed by a raised area formed in an insert plate.

[0059] Figs. 11c and 11d show another example, in lengthwise views (Fig. 11c, Fig. 11d), of displacers positioned in a flow channel with a square cross-section, the displacers in the variants shown being formed by raised areas formed in insert plates; and

[0060] Figs. 12a, 12b, 12c and 12d show other variants of another example of a flow guide device positioned in a flow channel with a square cross-section, the flow guide device having deflector plates.

[0061] A laminar flow 10 of a fluid 12 (Fig. 1a) is a flow with internal friction but without vortex formation. The internal friction results from the flow dynamics between the molecules of the fluid. The friction arises only inside the flowing medium between adjacent layers of fluid 14a, 14b, the individual fluid layers moving at different speeds and sliding past each other. In dependence on a flow channel 16, in which the fluid 12 is flowing, a velocity profile 18 then forms, fluid layer flows of different velocities being present in the individual fluid layers 14a, 14b.

[0062] The laminar flow 10, which is made up of the sum of the fluid layer flows, has a main flow direction 22.

[0063] Because the fluid velocity is zero in fluid layers 24 directly next to the channel walls 26 of the flow channel 16, the shape of the velocity profile 18 depends on the design of the flow channel 16.

[0064] Figs. 1a and 1b show a flow channel with a square cross-section 28, which is closed on all sides.

[0065] A laminar flow 10 forms when the Reynolds number of the flow is low – below 2300 in the case of a channel flow. Since the Reynolds number is defined as the product of a characteristic length and the flow velocity, divided by the kinematic viscosity, a laminar flow 10 is present when the transverse dimensions of the flow channel 16 are small and the flow velocity is low.

[0066] In electrochemical cells, and fuel cells especially, atmospheric oxygen is supplied in an air flow as an oxidising agent to catalytically active, flat extended electrodes (not shown in the drawing). In mobile fuel cells in particular, there are

flow channels of small dimensions in order to achieve high integral density and power density. The Reynolds number of the air flow is accordingly low, and the flow itself, in flow channels of this type, is laminar with high stability. Fig. 2a shows, in diagram form, a flow channel 30 of this type for an electrochemical cell. This flow channel 30 is, for example, essentially square in cross-section 32 (Fig. 2b), and is – in the example shown in Fig. 2 – open on one side 34 of the channel. In this way atmospheric air, as a released substance, can be removed at the open side of the channel from the laminar air flow 36 in the form of a fluid flow, i.e. a release surface of the air flow 36 faces towards the open side 34 of the channel, and – via this release surface – a depletion of the oxygen in the air flow takes place.

[0067] The transporting of oxygen in the air flow 36 between individual fluid layers of the laminar flow at right angles to the main flow direction 38 is essentially effected by diffusion only. Because the air flow 36 is in the form of a laminar flow, there is no other exchange of matter. This means that a concentration gradient of the oxygen levels in the air flow 36 is formed perpendicular to the open side 34 (Fig. 2c). The transporting of atmospheric oxygen in a direction of movement 40 at right angles to the main flow direction 38 is impeded, and the closer a fluid layer is to the release surface, and thus to the open side 34 of the channel, the easier it is for such an air layer to give off atmospheric oxygen. Therefore, as shown in Fig. 2c, the concentration of oxygen, as a substance which gives off air in the form of a fluid, is reduced in the areas 42 close to the surface, and increased in the areas 44 far away from the surface. In this way, a concentration gradient is formed in the laminar air flow, along the direction of movement 40 of the substance and thus perpendicular to the open side 34 of the channel.

[0068] In a first example of a device in accordance with the invention, as shown in Fig. 3a, a flow guide device – the device as a whole being numbered 48 – is positioned in the flow channel 30.

[0069] The flow guide device 48 comprises a flow deflector 50, which is spiral in shape. This flow deflector 50 imparts a swirl motion to a fluid flow 52 in the flow channel 30, with the result that fluid layers are spatially rearranged in relation to the open side 34 of the channel, and in particular relative to the transport direction 40 of the substance.

[0070] As a result of this, fluid layer flows move from areas further away from the open side 34 of the channel to areas that are closer to it and, conversely, fluid layer flows from areas that are closer move to areas that are further away. Fluid layers that have a lower substance content, following the release of the substance by the fluid from areas closer to the open side of the channel, are therefore moved away from the surface of the fluid, and fluid layers with a high substance content are moved towards the surface, in order to provide an improved release of the substance over the overall flow as a whole. (These circumstances are reversed correspondingly where a substance is to be taken up at the surface of the fluid.) This spatial rearrangement of the fluid layers thus acts against the formation of a concentration gradient as illustrated in Fig. 2c, so that the overall release of the substance over the surface of the fluid flow 52 is improved. (Correspondingly, substance uptake is improved when a substance is to be supplied to the surface.)

[0071] In the example shown in Fig. 3a, a spiral flow deflector with a helical angle of 180° is positioned in the flow channel 30. However, angles of rotation that are larger or smaller than 180° can be used. A lengthwise direction of this flow deflector 50 is essentially parallel to a lengthwise direction of the flow channel 30, and is thus also essentially parallel to a main flow direction of the fluid flow 52.

[0072] The length of the flow deflector 50 is, in this example, essentially the same as the length of the open side 34 of the channel, i.e. the length of the flow deflector 50 has the same dimensions as the length of the surface across which the release or uptake of the substance takes place.

[0073] The view 54 shows the flow deflector 50 inside the flow channel 30 in cross-section.

[0074] In another example, shown in Fig. 3b, the flow guide device includes a flow deflector 56 that consists of a number of helical structures 58 positioned at intervals inside the flow channel 30. One of these helical structures has a helical angle of 180°, for example.

[0075] In the example shown in Fig. 3c there is a corresponding flow deflector 60 made in the same way as the deflector 56 in Fig 3b. However, the separate helical structures 58 are here joined by fixed links 62. This makes the flow deflector 60 easier to handle, and, in particular, makes it easier to assemble in the flow channel 30.

[0076] In another example of a flow deflector 64 shown in Fig. 3d, the deflector is in the form of a spiral strip consisting of a regular sequence of helical structures 66. In this way a chain of helical structures 66 is formed.

[0077] Fig. 4 is a graph showing the results of a numerical simulation on a flow channel as in Fig. 3a with a flow deflector 50; however, in this case the flow deflector is not positioned over the entire length of the flow channel but only over a part section. P is a point along the length of the flow channel. One end of the flow deflector 50 is placed at the position 68, and is 4 mm in length. The flow channel itself has a length of approximately 300 mm, i.e. the part section of the flow channel covered by the flow deflector 50 is about 1.3% of the full length of the channel.

[0078] The vertical axis represents a current density distribution V obtained numerically in simulation, defined as the current density with the flow deflector 50 relative to the current density without the flow deflector 50, relative to 1.

[0079] The current density is the density of the current in an electrochemical cell based on electrochemical reactions, and is determined by the supply of oxygen as an oxidising agent. This supply of oxygen is, in turn, determined by the transporting of atmospheric oxygen from the flow of air in the form of a fluid in laminar flow.

[0080] As the graph in Fig. 4 shows, the flow deflector 50 causes, in the part section of the flow channel, an increase in current density of up to 12% locally. The increase in current density is not limited to the part section itself but extends over several more centimetres of the channel, covering roughly about 17% of the length of the channel, even though the flow deflector 50 takes up only about 1.3% of this channel length.

[0081] The flow detector 50 thus significantly encourages the release of atmospheric oxygen over the surface of the air flow, fluid layers of the laminar flow being spatially rearranged and, in particular, a swirl motion being imparted to fluid layer flows, the latter being given a transverse velocity component in the area of the flow deflector 50.

[0082] In another example, shown in Figs. 5 and 6a, there is a tubular flow channel 70 with a semicircular cross-section 72. On the walls 74 is positioned a spiral structure 76, which imparts a swirl motion to the laminar fluid flow and thus brings about a rearrangement of the fluid layers relative to a cross-sectional direction 78.

[0083] A substance can then be removed from the fluid towards an open side 80 of the channel, or a substance can be introduced into the fluid through this open side 80, this release or uptake not being impeded by any sharp concentration gradient resulting from the laminar flow.

[0084] The structure 76 can be made easily by integrating it into the walls 74 of the channel, structures 76 of this type being produced, for example, by embossing or pressing or injection moulding. Undercuts should be avoided as far as possible when carrying out these processes.

[0085] Fig. 6b shows variant of a structure 76 which comprises a "groove" 82 formed in a convex manner on the walls 74 of the channel, i.e. set into the walls.

[0086] Fig. 6c shows, as another example, a concave "groove" 84 which protrudes from the walls 74 of the channel.

[0087] In another example, shown in Figs. 7a and 7b, a flow channel 86 has, for example, a square cross-section 88 and is open on one side 90. Inside the flow channel 86 there is a wedge-shaped displacer 92, or this forms part of the flow channel 86.

[0088] The displacer 92 has a steeply tapered face 94 and another face 96. The other face 96 preferably has its perpendiculars aligned parallel to the lengthwise direction of the flow channel 86, thus being positioned at right angles to the main flow direction of the fluid in the flow channel 86.

[0089] In the example shown in Figs. 7a and 7b, the displacer 92 extends over the entire cross-section of the flow channel, i.e. the width of the other face 96 is essentially the same as the internal distance between the walls 98a and 98b of the flow channel 86.

[0090] The displacer 92 takes up only part 100 of the height of the flow channel 86, for example half the height of the flow channel 86 (left-hand part of Fig. 7a).

[0091] In the example shown in Fig. 7a, the angled face 94 faces towards the main flow direction of the fluid, i.e. the angled face 94 stands perpendicular to a base 102 of the flow channel 86.

[0092] A fluid flowing in a laminar manner in the flow channel, i.e. a fluid flowing in fluid layers with fluid layer flows of different speeds, encounters the displacer 92, in particular its angled face 94, and is deflected by it. The effect of this is that fluid layers "peel off" from the channel walls, and especially from the channel walls 98a and 98b, resulting in a rearrangement of the fluid layers (cf Figs. 7a and 7b). Because the displacer 92 is placed only in a part section of the flow channel 86, so that the laminar flow and, in particular, the fluid layer flows have to flow around it, at least parts of the fluid layer flows are given a transverse velocity component towards the open side 90, i.e. towards the uptake surface or release surface.

[0093] In a variant of an example shown in Fig. 7c, a number of wedge-shaped displacers 104 are positioned in the flow channel 86. A displacer 104 of this type has, in principle, the same shape as the displacer 92 described above in relation to Fig. 7a, and is arranged in the same way.

[0094] The arrangement of the several displacers 104 is, in particular, regular, i.e. the individual displacers 104 are positioned at the same distance from each other. It is preferable for the several displacers 104 to be arranged over the length of the flow channel 86 above which an uptake surface or release surface is to be in operation.

[0095] In another example, shown in Figs. 8a and 8b, a pair 110 of wedge-shaped displacers 112, 114 is positioned inside a flow channel 106 with an open side 108, this channel being fundamentally the same shape as the flow channel 86. The displacer 112 has an angled face 116 and another face 118. The latter is preferably aligned with its perpendiculars parallel to a lengthwise direction of the flow channel 106. This other face 118 occupies – as shown for example in the left-hand part of Fig. 8a – a part section of the flow channel 106 relative to both the height and width of the latter.

[0096] The second displacer 114 of the pair 110 of displacers is, in principle, the same as the first displacer 112, having an angled face 120 and another face 122, which is essentially positioned parallel to the lengthwise direction of the flow channel 106. This other face 122 also occupies a part section of the flow channel 106 relative to both the height and width of the latter.

[0097] The two displacers 112 and 114 of the pair 110 of displacers are offset in relation to each other at their other faces 118, 122 relative to the width of the flow channel 106, with the result that these two other faces 118 and 122 lie essentially in a single plane.

[0098] In addition, the displacers 112, 114 of the pair 110 of displacers are aligned against each other in such a way that the perpendiculars of each of the angled faces 116 and 120 lie at right angles to each other.

[0099] The angled face 116 of the displacer 112 is, for example – as shown in Figs. 8a and 8b – aligned perpendicular to a base 124 of the flow channel 106, and the angled face 120 of the second displacer 114 is essentially perpendicular to walls 126 of the flow channel 106.

[0100] The alignment of the angled faces 116 and 120 is here, in particular, such that fluid layer flows moving parallel to the lengthwise direction of the flow channel 106

flow towards the angled face 116 of the first displacer 112; this means that the angle between the angled face 116 and the walls 126 is a small positive acute angle. Moreover, the angled face 120 is aligned in such a way that it forms a small negative acute angle in relation to the base 124. In this way, the laminar flow is able to flow without interruption even at the transition between the two displacers 112, 114 at the other faces 118, 122.

[0101] By positioning a pair 110 of displacers in the flow channel 106, under the invention a rearrangement is effected of the fluid layer flows of the laminar flow, in that fluid layer flows are given a transverse velocity at right angles to the main flow direction of the laminar flow. In particular there is a fluid rearrangement from the closed channel walls towards the open side 108, i.e. in particular from the base 124 towards the open side 108; however, in particular because of the positioning of the angled face 116, there is also a rearrangement of layers between adjacent channel walls 126.

[0102] In a variant, shown in Fig. 8c, a number of pairs 110 of displacers are positioned – in particular at regular intervals – in the flow channel 106.

[0103] Fig. 9 shows a graph based on the results of numerical simulations. They are based on a square channel geometry as in Fig. 8c, with a number of regularly spaced pairs 110 of displacers which are shaped as shown in Fig. 8a, these pairs of displacers being positioned along the entire length of the flow channel 106. On the x axis, the point P in the channel is given in mm in its lengthwise direction (i.e. the channel has a length of 300 mm); the y axis shows the current density I in mA/cm^2. The current density here is that of an electrochemical cell to which is supplied, in a laminar air flow, atmospheric oxygen as an oxidising agent via a flow channel 106 of this type.

[0104] The line 128 in the graph of Fig. 9 shows the current density without the pairs 110 of displacers. It can be seen that the current density, as expected, declines as the distance from the beginning of the channel increases, since the layers near the surface become increasingly depleted of atmospheric oxygen, and the transport of atmospheric oxygen between the laminar layers takes place essentially by diffusion only, with the result that the release of oxygen over the surface of the laminar air flow deteriorates as the distance increases.

[0105] The line 130 shows the effect of the flow guide device with the pairs 110 of displacers. The current density I displays an oscillatory behaviour in accordance with the regular positioning of the pairs 110 of displacers, and lies above the line 128. Localised peaks occur where the wedge-shaped pairs 110 of displacers are positioned. The overall level of current density is higher on the line 130 than on the line 128, the increase being of about 10% – and with negligible pressure losses. This increase represents an improvement in the output of the electrochemical cell.

[0106] Another example is shown in Figs. 10a and 10b. Inside a flow channel 134 is positioned a pair 136 of displacers, with a wedge-shaped displacer 138 and a wedge-shaped displacer 140. The displacer 138 again has an angled face 142 and another face 144, the latter being positioned essentially perpendicular to a lengthwise direction of the flow channel. This other face occupies essentially the entire cross-

section of the flow channel 134, and a part section of the latter's height. The angled face 142 stands perpendicular on a base 146 of the flow channel 134.

[0107] An angled face 148 of the displacer 140 of the pair 136 of displacers is positioned essentially perpendicular to walls 150 of the flow channel 134. Another face 152 of the second displacer 140 is positioned essentially perpendicular to a lengthwise direction of the flow channel 134, and occupies essentially the entire height of the flow channel 134 relative to the distance between the base 146 and an open side 154, this other face occupying only a part section of the flow channel relative to the cross-section (cf the left-hand part of Fig. 10a).

[0108] The angled face 142 of the first displacer 138 of the pair 136 of displacers is at a small positive acute angle in relation to a wall 150 of the channel, and the angled face 148 of the second displacer 140 is at a small positive angle in relation to the base 146 of the flow channel 134.

[0109] The arrangement of the displacers 138, 140 in the flow channel 134, as illustrated in Figs. 10a and 10b, also causes a rearrangement of the fluid layers in the laminar flow of a fluid, in order thus to improve the surface uptake or surface release of substances, for example atmospheric oxygen, in a fluid – air, for example – in laminar flow.

[0110] In the variant of an example shown in Fig. 10c, a number of pairs 138 of displacers are positioned in the flow channel 134. These are, in particular, arranged in a regular manner and thus at equally spaced intervals in the flow channel.

[0111] In another example, which is shown in Figs. 11a and 11b, an insert 158 – for example in the form of an insert plate – is positioned in a flow channel 156 which has, for example, a square cross-section. This insert 158 is in the form of a bulge, and has a raised area 160 which acts as a displacer, i.e. the fluid is unable to pass through the raised area 160.

[0112] The insert 138 also has an opening 162 adjacent to the raised area 160, so that fluid layer flows deflected at the raised area 160 are able to flow through the opening 162.

[0113] The insert 158 is preferably positioned over the entire cross-section of the flow channel 156 (cf the left-hand part of Fig. 11a) and positioned, relative to the height of the flow channel 156, between a base 164 and an open side 166 in such a way that the raised area 160 is positioned over a part section of the height of the flow channel 156. The raised area 160 forms, for example, an acute angle with the base 164, and ends about half-way up relative to the distance between the base 164 and the open side 166 of the flow channel 156[2].

[0114] The raised area 160 is, for example, punched or embossed in a deflector plate acting an insert 158.

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[2] Translator's note: given as 154 in the original text, but it should be 156. 154 is in Fig. 10b.

[0115] The fluid flow in the area of the insert 158 is able, in the area of the insert, to pass into the latter via an open end 168, is then deflected over the raised area 160, and is able to exit at the opening 162. In this way, a rearrangement of the fluid layer flows occurs from the area near the base 164 to an area near the open side 166, i.e. fluid layers are deflected from areas far from the surface to areas close to the surface.

[0116] In the variant shown in Figs. 11c and 11d, there are inserts 158 in the flow channel 156 positioned at regular intervals. It is also possible here to replace the regularly spaced inserts 158 by a single insert, which is placed in the flow channel 156 accordingly.

[0117] In particular, the openings 162 are spaced at intervals, and in particular at regular intervals to one another. The openings 162 lie here in the flow channel 156 in particular essentially in a single plane.

[0118] However, an alternative variant is also possible, in which the heights of the individual openings 162 are different relative to the base 164, i.e. in which the openings 162 are offset in relation to each other in terms of height.

[0119] Particularly where the several inserts 158 are formed by a single insert, as illustrated in Figs. 11c and 11d, there is, between adjacent openings, in each case at least one additional fluid exchange opening 170 which allows a fluid exchange between the area 172 above the inserts 158 (or the single insert) and the area 174 below the inserts 158 (or the single insert). By this means, fluid layer flows which are deflected by the raised areas 160 into the area 172 are able to flow again through the fluid exchange openings 170 into the area 174, so that they are able in turn to flow into the open ends 168 and then be again deflected by the appropriate raised areas into the areas 172.

[0120] In another example, shown in Fig. 12a, the flow channel is made fundamentally the same as that described in Figs. 11a to 11d. The same reference number is therefore used for the flow channel. In the embodiments shown in Figs. 12a to 12d, an insert is placed in the flow channel 156. As shown in Figs. 12 and 12b, the insert 176 comprises a displacer 178, which is in the shape of a cuboid, for example, the diagonal of which is aligned essentially parallel to the lengthwise direction of the flow channel 156, and which reaches – from the base 164 of the flow channel 156 – part-way up the flow channel 156. The cuboid 178 can be made of punched and folded sheet metal, and it can be open at the top or also closed.

[0121] The insert 176 with the displacer 178 is, for example, punched from a metal strip or is an appropriately embossed deflector plate.

[0122] The displacer 178 deflects fluid flows in order to bring about a rearrangement of fluid layers of the laminar flow.

[0123] In the variant shown in Fig. 12c also there is an insert 180, with a displacer 182 which is fundamentally the same as the displacer 178. However, one edge 184 of the square-shaped displacer that faces the open side 166 is chamfered, i.e. the edge is bevelled. This encourages the deflection of fluid layer flows even more.

[0124] In a variant of an example shown in Fig. 12d, a number of inserts 186 are positioned in the flow channel 156 along the length of this flow channel 156. In particular, the inserts 186 are positioned in a regular manner and, in particular, at equal intervals.

[0125] In the variant shown there is an insert 188 with, for example, two displacers 182 – as described in relation to Fig. 12c – positioned apart from each other. The two displacers 182 are aligned in such a way that their diagonals lie along the same line.

[0126] It is also possible for two displacers 182 to be positioned offset in relation to each other in an insert 190, i.e. their diagonals are positioned apart from each other.

[0127] In particular, different combinations of these inserts 188 and 190 can be positioned in the flow channel 156.

[0128] The displacers 112, 114 or 138, 140 or 158 or 178 can be manufactured, for example, by deep-drawing or embossing metal plates, or for example by injection moulding or pressing polymer-bonded graphite plates.

[0129] What the flow devices of the invention have in common is that fluid layers of the laminar flow are rearranged, i.e. a rearrangement of layers occurs relative to a release surface of uptake surface for a substance. In particular, fluid layer flows are given a transverse velocity component at right angles to a main flow direction of the laminar flow, in order to bring about a change of direction in such fluid layer flows.

Claims

1. Device to encourage the surface uptake and/or surface release of a substance by a fluid, comprising a flow channel (30) in which a laminar flow of the fluid can be formed, at least one flow guide device (48) being provided, which is positioned in the flow channel (30) in such a way, and formed in such a way, that it brings about a spatial rearrangement of fluid layers (24) in the laminar flow.

2. Device as in Claim 1, characterised in that the at least one flow guide device (48) is positioned and formed in such a way that, by means of it, layer flows (20) of the laminar flow are given a transverse velocity component.

3. Device as in Claim 1 or 2, characterised in that the at least one flow guide device (48) is positioned and formed in such a way that a rearrangement of fluid layers (24) of the laminar flow occurs in such a manner that fluid layer flows (20) are deflected from areas of the flow that are closer to the uptake surface or release surface of the fluid towards areas that are further away.

4. Device as in one of the preceding Claims, characterised in that the at least one flow guide device (48) is positioned and formed in such a way that fluid layer flows (20) are deflected from areas of the flow that are further away from the uptake surface or release surface of the fluid towards areas that are closer to this surface.

5. Device as in one of the preceding Claims, characterised in that the at least one flow guide device (48) is positioned and formed in such a way that the flow in the flow channel (30) is essentially free of turbulence.

6. Device as in one of the preceding Claims, characterised in that the at least one flow guide device is positioned and formed in such a way that fluid layer flows (20) of different fluid layers intersect one another.

7. Device as in one of the preceding Claims, characterised in that the at least one flow guide device (48) comprises a structure (50; 76; 92; 158; 176), the dimensions of which vary at right angles to the flow direction (22) of the laminar flow.

8. Device as in one of the preceding Claims, characterised in that the at least one flow guide device (48) is positioned and formed in such a way that an essentially regular rearrangement of fluid layers (24) takes place along the flow channel.

9. Device as in Claim 8, characterised in that the at least one flow guide device (48) comprises a number of flow-guiding structures (66; 104; 110; 136; 158; 186) which are positioned at regular intervals relative to the lengthwise direction of the flow channel.

10. Device as in one of the preceding Claims, characterised in that the at least one flow guide device comprises a flow deflector (50) which imparts a swirl

motion to the fluid in the laminar flow.

11. Device as in Claim 10, characterised in that the flow deflector (50) has a helical structure (58).

12. Device as in Claim 10 or 11, characterised in that a lengthwise axis of the flow deflector (50) is aligned parallel to the lengthwise direction of the flow channel (30).

13. Device as in one of Claims 10 to 12, characterised in that the flow deflector (50) is positioned in the flow channel (30).

14. Device as in one of Claims 10 to 12, characterised in that the flow deflector (60) is formed by walls of the channel.

15. Device as in Claim 14, characterised in that walls of the channel have a concave structure (82) to form the flow deflector.

16. Device as in Claim 14, characterised in that walls of the channel have a convex structure (84) to form the flow deflector.

17. Device as in one of the preceding Claims, characterised in that the flow guide device comprises one or more displacers (92; 112; 114; 138; 140; 158; 178; 182) which are obstacles for the flow in the flow channel.

18. Device as in Claim 17, characterised in that a displacer (92) is wedge-shaped.

19. Device as in Claim 18, characterised in that a wedge-shaped displacer (92) is positioned in such a way that its angled face (94) faces towards the flow direction of the laminar flow.

20. Device as in Claim 18, characterised in that the flow guide device comprises at least one pair (110) of wedge-shaped displacers (112, 114).

21. Device as in Claim 20, characterised in that the angled faces (116, 120) of a pair (110) of displacers are positioned at right angles to each other.

22. Device as in Claim 20 or 21, characterised in that the displacers (114, 116) of a pair (110) of displacers are positioned at right angles to each other.

23. Device as in one of Claims 20 to 23, characterised in that the displacers (112, 114) of a pair (110) of displacers are positioned offset relative to each other in a transverse direction of the flow channel (106).

24. Device as in one of Claims 20 to 23, characterised in that the angled faces (116, 120) of a pair (110) of displacers have opposing component vectors relative to the lengthwise direction of the flow channel (106).

25. Device as in one of Claims 17 to 24, characterised in that a displacer is positioned and formed in such a way that fluid layer flows can be deflected

from first walls of the flow channel towards second walls of the flow channel.

26. Device as in one of Claims 17 to 24, characterised in that a displacer is positioned and formed in such a way that fluid layer flows (20) can be deflected from closed walls of the flow channel towards open walls of the channel.

27. Use of the device as in one of the preceding Claims in an electrochemical cell.

28. Use as in Claim 27 in an electrolyser.

29. Use as in Claim 27 or 28 in a fuel cell.

30. Use as in one of Claims 27 to 29, characterised in that the flow channel leads to an electrode in order to supply it with oxygen.

31. Method for encouraging the surface uptake and/or surface release of a substance by a fluid which is moving in laminar flow, within which flow fluid layers of the laminar flow can be rearranged by a flow guide device.

32. Method as in Claim 31, characterised in that fluid layer flows are given a transverse velocity by the flow guide device.

33. Method as in Claim 31 or 32, characterised in that fluid layer flows are deflected from the area of the uptake surface or release surface into areas that are further away.

34. Method as in one of Claims 31 to 33, characterised in that fluid layer flows are deflected from areas that are further away towards the uptake surface or release surface.

35. Method as in one of Claims 31 to 34, characterised in that the fluid is given a swirl motion.

36. Method as in one of Claims 31 to 35, characterised in that the fluid layer flows are deflected in an essentially turbulence-free manner.

Seven pages of drawings follow.
